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In support to the United States Government in its goal of halting the production of illegal narcotics, the Defense Mapping Agency has begun production of a series of Landsat image maps. Produced at a scale of 1:100,000, these Landsat image maps are compiled from recent Landsat Thematic Mapper scences. Bands 7, 4, and 2 are combined in a false color composite. Intensification of selected features provides improved topographic detail. The enhanced Landsat imagery is combined with UTM grid and margin information and compiled and color sepatrated in a digital environment. The MPE output is film separates, printed via a large format laser filmwriter. In support of this new production system, a unique development/ production environment was created to bring the Government cartographers into direct contact with the system developers in order to facilitate rapid modifications and changes to the software as necessary.

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DIGITAL PRODUCTION OF LANDSAT IMAGE MAPS IN THE MAP PUBLISHING ENVIRONMENT

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ABSTRACT

In support of the United States Government's counter narcotics activities, the Defense Mapping Agency has begun production of a series of Landsat image maps. Produced at a scale of 1:100,000, these Landsat image maps are compiled from recent Landsat Thematic Mapper scenes. Bands 7, 4, and 2 are combined in a false color composite. Intensification of selected features provides improved topographic detail. The enhanced Landsat imagery is combined with a UTM grid and margin information and compiled and color separated in a digital environment. The Map Publishing Environment (MPE) output is film separates, printed via a large format laser filmwriter. In support of this new production system, a unique development/production environment was created to bring the Government cartographers into direct contact with the system developers in order to facilitate rapid modifications and changes to the application software as necessary.

Keywords: Satellite photography; Topographic maps; Digital computers/maps; Color film separation; Composite images; Photographic images; Image intensification; Computer programs; Drug smuggling. (MM)

INTRODUCTION

Recent events in South America and the Persian Gulf have demonstrated the value for accurate, rapidly produced Landsat image maps. Whether it is an image map of the Upper Huallaga Valley in Peru or the Neutral Zone between Iraq and Saudi Arabia, the demand for this type of map continues to grow. The Defense Mapping Agency (DMA) is committed to providing our customers with new and innovative products. The 1:100,000 scale Landsat image map is one of these products. DMA has developed a modern, digital production system designed to create Landsat image maps in an accurate and rapid production environment. This system, the "Map Publishing Environment" (MPE) is capable of exploiting multi-spectral imagery. MPE has the ability to create and view, on the workstation, true cyan, yellow, magenta and black (CYMK) color separates which allows for great flexibility in production of the final digital half-tone film separates.

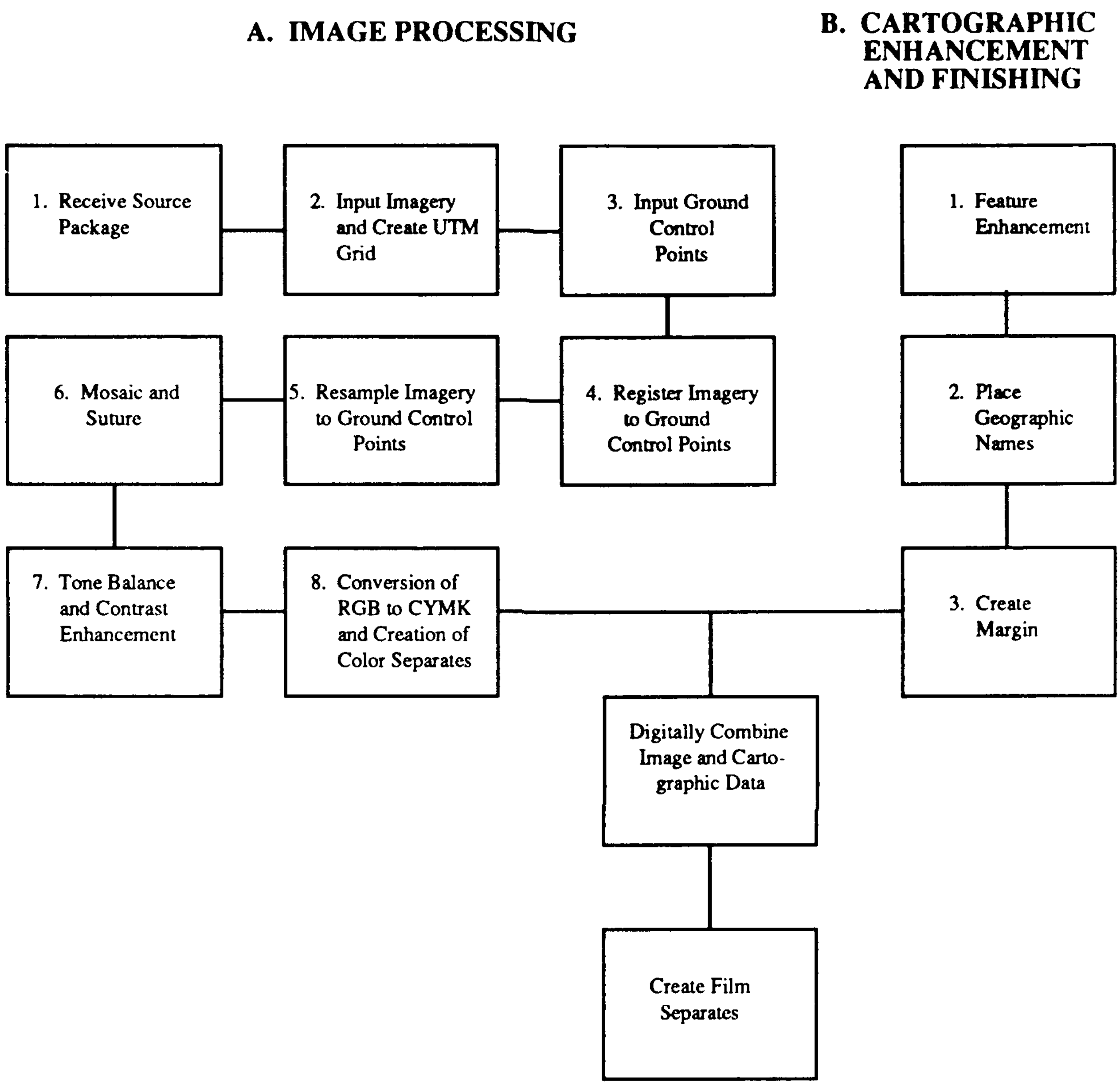
DMA has possessed the capability to perform image processing of multi-spectral imagery since the inception of the data type. Our strengths lay in our personnel, who are well versed in the science of image processing. Landsat and SPOT image analysis in support of hydrographic charting and the Notice to Mariner program at the DMA's Hydrographic/Topographic Center has been in place since 1976. It has become evident that the present systems, while sufficient for current needs, would be inadequate to handle the large, new requirements. In addition to new hardware systems, new production techniques are necessary to be able to respond rapidly to customer requirements. Multiple, operator dependent image processing decisions concerning variables such as contrast enhancement and filtering must be made uniform to insure a consistent appearance for a series of image maps over a specific geographic area.

MPE overcomes these past shortcomings by providing a modern suite of hardware and software. The system is comprised of 12 workstations, four of which are designated as image processing workstations. The image processing workstation has a 32 bit color display, a 10 MIP RISC microprocessor and 80 MB of RAM. Each workstation contains four 670 MB disk drives for image data and software storage. The system currently contains four output devices; a color thermal printer, color electrostatic plotter, color drum-type proof plotter and a laser filmwriter. The workstations are connected via a local area network to a file server and the output devices. The operating system is UNIX based. The user interface is icon and menu oriented. Most commands are entered into the system by driving a cursor and selecting options displayed on the workstation screen. The applications software includes image processing module that provides for analysis and manipulation of multi-spectral imagery. Filtering, contrast enhancement via look-up tables, resampling, edge detection and Fourier analysis are among the available image processing functions that can be performed. Projection and grid generation and raster and vector editing capabilities also exist in MPE. Color separation software allows for display of the CYMK color separates on the workstation screen in a format that accurately portrays their final appearance.

The following is an account of how Landsat image processing at DMA has moved from a developmental realm into an accelerated production environment. DMA's responsiveness to our customers' needs is demonstrated in how current events caused rapid evolution of MPE from a development program with limited production into a quick response ad hoc production center.

PRODUCTION

The 1:100,000 Landsat image map is a combination of enhanced, resampled Landsat Thematic Mapper (TM) imagery with selected feature enhancement, geographic names, UTM grid and margin information. The following is a description of the Landsat image map workflow.



A. IMAGE PROCESSING

1. Receive Source Package.

The workflow begins when the cartographer receives the source package. The source package contains the geographic names guide, selected ground control points with their associated geographic coordinates and any ancillary data. Also included in the source package is the P level, digital Landsat TM imagery in band sequential format, on a Space Oblique Mercator projection. Extensive cloud cover over rainforests, at any one time, may require multiple date scenes to be pieced together to create one relatively cloudless image map.

2. Input Imagery and Create Grid.

The cartographer loads and inputs the Landsat tape into the system. A UTM grid on the WGS-84 datum is created and the grid interval, grid color and line weight are determined.

3. Input Ground Control Points.

The geographic coordinates of the ground control points from the source package are read into the system by the cartographer and form the basis for the ground control file. Six to ten equally distributed ground control points are desired for each Landsat image map to ensure geometric accuracy.

4. Register Imagery to Control Points.

The cartographer registers the imagery to the ground control file by interactively placing the ground control point on the corresponding pixel in the Landsat image. A listing of residual values from the affine transformation are then displayed. If the resulting ground control residual values are unsatisfactory, ground control point(s) can then be either redefined on the image or removed from the transformation calculation entirely.

5. Resample Imagery to Control Points.

The imagery is now resampled into an orthogonal box which encompasses the geographic sheet boundary. A cubic convolution interpolation is applied to the control point file. The pixel size is resampled to 25 meters. At this point it becomes evident to the cartographer if adjacent imagery will be necessary to be mosaicked to the original scene, to provide complete coverage for the 1:100,000 Landsat image map

6. Mosaic and Suture.

Any additional, adjacent scenes necessary to complete the sheet are now mosaicked to the original scene. Ground control points are selected and the adjacent scene is registered and resampled into the sheet boundary as in the previous steps. Although the most cloud-free scenes of recent imagery are chosen for the image map, areas of clouds are still common. It is at this point that any extensive areas of clouds are "cut" out of the image. The cartographer draws a polygon around the cloud obscured area with the cursor. This polygon is then removed from the image. Other date imagery is then checked for a cloud free scene of the same area. If a suitable cloud free scene is located, it is registered and resampled into the same polygon of the original scene using ground control points and common tie points in the areas of overlap.

7. Tone Balance and Contrast Enhancements.

Sutured areas from different date imagery will have different brightness values due to varied sun angles. To lessen the piecemeal effect of sutured areas on the image map, histogram matching is performed. The cartographer collects a histogram of the brightness level over the sutured area. This histogram is automatically compared to the histogram of the imagery contained in the image map and a matching function is performed. A suture area is darkened or brightened to match the surrounding image. Once histogram matching is performed, the suture area "blends" in with the original image and is hard to detect.

At this point, with the image resampled to ground control, extensive cloud areas sutured out, and all histograms of sutured-in areas matched, contrast enhancement of the image can begin. In the past, contrast enhancement was often a slow, iterative process. A certain "look" was designed for an image that optimized the interpretation of the features in that image. This "look" or contrast enhancement was customized for a particular image. In producing a series of 80 to 100 image maps over an area, a custom contrast enhancement for each sheet is not practical or desirable. A contrast enhancement technique has been developed that provides a uniform appearance for all sheets in a project area. In a high production environment, this uniform contrast enhancement was necessary to ensure consistency and efficiency in producing large numbers of image maps.

All the scenes of the project are mosaicked together and one optimum contrast enhancement is developed for the "super-scene". This enhancement is applied to each

Landsat image map via the histogram matching function. The result is a series of image maps that are consistent in appearance and efficient to produce.

8. Conversion of RGB to CYMK and Creation of Color Separates.

The cartographer is now ready to create the image map color separates. This step involves translation of the red, green, and blue (RGB) values (additive color data) to the printing colors of CYMK (subtractive color data). This is accomplished using the color separation software. This software takes RGB data as input and generates digital CYMK color separates that are necessary for the lithographic plate production. Tables are constructed by the software that drive the separation process. These tables are built incorporating parameters that determine how the separations will appear in their final form. An additional software package allows an interactive display of the CYMK files generated by the color separation software. Analysis of this display will determine if color adjustment is necessary, the cartographer is able to interactively do that adjustment at this point, to achieve standard color tones on the final lithographic prints.

B. CARTOGRAPHIC ENHANCEMENT AND FINISHING

1. Feature Enhancement.

Cartographic enhancement of selected features such as roads, railroads, airstrips, and buildings is done to provide more detail than is normally available using TM imagery. Using a high resolution digitizing table, the cartographer geographically registers the source to the Landsat image map. Selected features are then digitized from the alternative source. The symbology used to portray the features is selected by the cartographer from a pre-defined symbol table. The symbols are in vector format for ease in placement and manipulation. The vector feature overlay is then converted into a raster format suitable for merging with the image data.

2. Place Geographic Names.

Using a transliteration and placement guide contained in the source package, the cartographer places the raster format geographic name on the image in correct relation to the feature it describes. The names appear on the image in the desired type font and type size as defined in the product specification.

3. Create Marginalia.

The Landsat Image map margin is similar to the DMA Topographic Line Map. The image map margin is a combination of scanned data, such as the DMA seal and unique, non-recurring data such as the sheet name and number. A master border is created and adapted for each image map. The grid values and geographic coordinates are selected and placed at this point. All type appears in the correct fonts and sizes. Colors and patterns of specific features are portrayed in a descriptive legend box.

Digitally Combine Image and Cartographic Data.

The imagery will now be combined with the feature overlay, the geographic names and the border. With all elements now in CYMK raster form, a check plot is produced on a 400 DPI color check plotter for a quality control check of the imagery, feature enhancements, names and border data.

Create Film Separates.

The cartographer sends the digital CYMK film separates to the large format laser filmwriter via the local area network link where reproduction quality 1000 DPI film separates are generated. The high speed filmwriter produces a full format image map separate in approximately 30 minutes. The film separates are then used to create a photographic proof of the image map. This photographic proof is used as a last quality control check and as a guide to the DMA Graphic Arts department in their creation of lithographic plates used to print the Landsat image map.

TRAINING

The usual training scenario for a new mapping, charting or geodetic production system is to provide the initial prerequisite training at the Production Center and slowly increase production as the trainees became more knowledgeable. In the Map Publishing Environment, the trainees were moved to the contractor's facility for a four month program of intensive training and actual production. A short course in the basic theories of multi-spectral imagery was provided to the trainees, followed by a UNIX operating system course, a graphics environment course and then an image processing software course. Each trainee received approximately five weeks of formal classroom lecture and practical lab exercises at the workstation.

Training at the contractor's facility provides the advantages of having support available as problems arise. Software adjustments were often made overnight. Questions about the software were answered quickly, as the software engineers and programmers were often literally standing behind the operators.

As formal instruction ended, a limited production program of 11 Landsat Image Maps for counter narcotics support was scheduled to begin. Coincidentally, at this time, Iraq invaded Kuwait. The limited production program was quickly changed from 11 sheets of rainforest to 129 sheets of desert. The problems of cloud cover in the imagery were replaced by concerns for producing roughly 10 times the number of image maps with the same number of personnel. A joint team was formed to perform this production. In a tribute to Government and contractor personnel cooperation, long hours were worked and weekends forgotten, until the desert Landsat image maps were completed. An added benefit of the accelerated production program was that a group of Government trainees received more experience in three months than in a year of normal production. In addition, the MPE system was extensively tested "under fire". The personnel and the system both performed far beyond what was expected.

CONCLUSION

Production of Landsat Image Maps in a production environment is not only possible, it is now reality at the DMA. The MPE streamlined workflow can quickly produce an accurate product to satisfy our customer needs. The Landsat image map is but one of the new products that are taking the Defense Mapping Agency into the 21st century.